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## **Changes in Muscular Activity While Imagining Weight Lifting Using Stimulus or Response Propositions**

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Investigating emotional imagery, Lang (1977, 1979) proposed a dichotomy between stimulus and response propositions. In this study, Lang's model is applied to movement images of lifting of 4.5 and 9 kg weights. Twenty-two male and 17 female students participated in the study. During the imaginary lifting of the weights, the electromyographical activity (EMG) of both biceps brachii muscles were assessed. Imagery ability was measured with the Movement Imagery Questionnaire (MIQ) and another self-report rating scale. When response propositions were emphasized in the script, imaginary weight lifting resulted in greater muscle activity than when stimulus propositions were emphasized. During imagined lifting, EMG activity of the active arm was greater than that of the passive arm. In addition, in the active arm, a significant difference in EMG activity was found between 9 kg and 4.5 kg. It was concluded that Lang's model is also applicable to emotionally neutral movement imagery.

Key words: imagery, EMG activity

In applied sport psychology, imagery takes a prominent position, and virtually all integrated psychological skills training programs include imagery (e.g., Bennet & Pravitz, 1982, 1987; Gauron, 1984; Suinn, 1980). Several theories have been proposed to explain the reported positive effects of imagery on sport skills, but none of the more traditional theories is completely satisfactory (Hecker & Kaczor, 1988; Murphy & Jowdy, 1992). In recent years Lang's (1977, 1979) bio-informational theory of emotional imagery has gained considerable interest in the domain of sport psychology. Lang's theory is centrally involved with emotional imagery and was originally developed to explain equivocal results in the treatment of various emotional disorders, especially different kinds of phobia. However, the theory might also provide a suitable theoretical framework for studying imagery in sport psychology. In this paper, two hypotheses are inferred from Lang's theory and are tested in a study of movement imagery.

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Following Pylyshyn (1973), Lang dismisses the metaphor of an image as a picture in the head, an analog representation of objects and events, like a photograph. Instead, Lang views the image as a propositional construct. This view begins with the assumption that the image in the brain is more like an elaborated description of specific affirmations about the world: "The image is a functionally organized, finite set of propositions" (Lang, 1977, p. 864). Imagery involves activation of a network of propositionally coded information stored in long-term memory. This information network is considered to be a prototype for overt behavior (Hecker & Kaczor, 1988, p. 365) or a preparatory set to respond (Lang, 1977, p. 867).

An emotional image contains two fundamental classes of statements: stimulus propositions and response propositions. Stimulus propositions describe the content of a scenario to be imagined, for example the physical details of an object or situation, object movement, physical place or general location, and presence or absence of observers. Response propositions contain assertions about behavior, such as verbal responses (e.g., cries), somatomotor events (e.g., muscle tension), and visceral events (e.g., heart rate, palmar sweat). Response propositions are expected to be accompanied by an efferent outflow appropriate to the image. Furthermore, images that contain response propositions are likely to produce more vivid images and to elicit more physiological responses than images that contain only stimulus propositions (e.g., Lang, Kozak, Miller, Levin, & McLean, 1980).

The distinction between stimulus and response propositions bears similarity to the distinction, introduced by Mahoney and Avenier (1977), between external and internal imagery perspective:

In external imagery, a person views himself from the perspective of an external observer (much like in home movies). Internal imagery, on the other hand, requires an approximation of the real-life phenomenology, such that the person actually imagines being inside his/her body and experiencing those sensations that might be expected in the actual situation. (p. 137)

Although imagery perspectives and the types of propositions distinguished in Lang's theory are not identical, it can be assumed that imagery from an internal perspective will activate more response propositions of the image, whereas imagery from an external perspective will activate mainly the stimulus propositions of the image (Hale, 1982; Hecker & Kaczor, 1988).

Lang et al. (1980) demonstrated that images of emotional scenes, as well as images of emotionally neutral action scenes, that contained response propositions resulted in more muscle tension and a higher heart rate than did images that contained primarily stimulus propositions. Furthermore, empirical evidence supports the contention that movement imagery from an internal perspective elicits more physiological responses than movement imagery from an external perspective (Hale, 1982; Harris & Robinson, 1986; Suinn, 1980). Hale (1982), for example, found that the internal perspective resulted in muscle activity during imagery of an arm movement, whereas the external perspective did not. Results of studies by Harris and Robinson (1986) and Suinn (1980), although less well controlled than the experiment of Hale, also lend support to the hypothesis of greater physiological responses in internal imagery of movements than in external imagery. The first hypothesis, derived from Lang's theory tested in this study, is that movement im-

agery will result in greater muscular activity when response propositions are emphasized in the script than when the script emphasizes stimulus propositions.

An important hypothesis proposed by Lang (1977, p. 884) is that imagery processing may lay down a new response prototype which then becomes the basis for overt behavior. As noticed by Hecker and Kaczor (1988), this process of establishing new response prototypes through imagery, might provide an explanation for the beneficial effects of imagery in motor actions and sport, reported in the literature (e.g., Feltz & Landers, 1983; Murphy & Jowdy, 1992). Imagining oneself shot-putting, for example, involves activating stimulus propositions that would include descriptions of the environment in which one operates. Response propositions would include muscular changes in the arm and shoulder and probably also in other parts of the body involved in performing this action. Imaginal rehearsal of shot-putting activates propositions that then become an appropriate set of instructions to perform the movement.

The assumption that the image functions as a model for overt behavior implies that the physiological response during imagery should be related to the content of the image. The physiological response should be specific to the imagined movement. For example, imagining a movement of the right arm should result primarily in activity of that arm,<sup>1</sup> and imagining lifting a heavy object should result in more muscular activity than imagining the lifting of a lighter object.

In order to test the specificity of the physiological response in this study, differences in muscular (electromyographic [EMG]) activity related to the nature of the image were investigated. Participants were instructed to imagine lifting dumbbells that differed in weight (4.5 or 9 kg), with their preferred arm. Thus, the second hypothesis tested in this study was that EMG activity would be greater in the imaginary active arm than in the passive arm and the imagined lifting of a 9 kg weight would produce more EMG activity than the imagined lifting of 4.5 kg.

It has been suggested by several researchers that imagery ability is a variable mediating the effectiveness of imaginal rehearsal (see Murphy & Jowdy, 1992, for an overview). Individuals who have a good imagery ability are supposed to have a greater control of their images and to create more vivid images than individuals whose imagery ability is poor. Imagery ability was, for example, found to be an important variable in studies examining the effect of mental practice on performance (Goss, Hall, Buckholz, & Fishburne, 1986; Ryan & Simons, 1981, 1982). Correlational studies indicate that successful athletes report having better control of their imagery (Meyers, Cooke, Cullen, & Liles, 1979; Orlick & Partington, 1988) and experiencing more vivid images (Highlen & Bennett, 1983) than less successful athletes. Consequently, it seems desirable to determine the imagery ability in order to prevent any confounding of the assessments caused by a difference in imagery ability between the participants. Furthermore, it may be hypothesized that better imagers will produce muscular activity patterns during imagery (when response propositions are emphasized) that will correspond more closely to the patterns observed with real movements than subjects who have less vivid images and more difficulty in controlling them. Therefore, the imagery ability of the participants in this study was measured. The resulting scores were used in the data analysis to test the third study hypothesis that study participants who produce muscular patterns that are more similar to the actual movement during imagery would have higher imagery ability scores than participants who produce patterns that are less similar to the actual movement.

## Method

### Participants

Twenty-two male and 17 female students volunteered to participate in the study. Their ages ranged from 18 to 31 years ( $M = 23.4$ ,  $SD = 3.19$ ). Ten participants (7 males and 3 females) were experienced body builders who exercised at least three times a week with dumbbells (which were, however, considerably heavier than the weights used in this experiment). The other participants had no experience in lifting dumbbells.

### Instrumentation

*Movement Imagery Questionnaire (MIQ).* To measure study participants' general imagery ability, a shortened version of the Dutch MIQ (Hall & Pongrac, 1983) was used. This version of the MIQ consists of six items designed specifically to measure imagery of movements and contains scales for measuring visual and kinesthetic imagery ability. Each item in the questionnaire represents a unique movement, and every movement is precisely described so that all individuals completing the questionnaire imagine the same movements. Participants were first requested to imagine the movement either visually or kinesthetically, in alternating order. Then they were asked to imagine the six movements again, with the two modalities given in reversed order. A variety of relatively simple arm, leg, and whole body movements are incorporated in the questionnaire. For each movement the participants first assumed a prescribed starting position and then actually executed the movement. After returning to the starting position, the execution of the movement was imagined. Finally, the difficulty participants experienced in imagining the movements was indicated on a 7-point rating scale ranging from 1 (*easy to imagine*) to 7 (*difficult to imagine*) (Goss et al., 1986). The reliability of the Dutch (complete) version of the MIQ is good. Cronbach alpha internal consistency coefficients are  $\alpha = .90$  (visual subscale) and  $\alpha = .91$  (kinesthetic subscale). Test-retest reliabilities of the subscales are  $r = .83$  and  $r = .75$ , respectively, at a time interval of 3 weeks (Schattel, 1992). Alpha's of the shortened versions are  $\alpha = .88$  (visual subscale) and  $\alpha = .85$  (kinesthetic subscale).

*Imagery Rating Scale.* To measure participants' visual and kinesthetic ability to imagine the lifting of a dumbbell, a 7-point Likert-type rating scale was used. On this scale, participants indicated how easy (1) or difficult (7) it was for them to imagine (visually or kinesthetically, respectively) the lifting movement.

*EMG Recordings.* To assess participants' muscular activity during imagery, EMG recordings were obtained of both biceps brachii muscles. On both arms two surface electrodes were attached over the origin and insertion ends of the muscle belly, and a reference electrode was placed on the ventral area of the passive forearm. The EMG signals of both arms were amplified (DISA, type 15C02 sensory amplifier: upper and lower frequency limits at 1 KHz [slope of 12 dB per octave] and 10 Hz [slope of 6 dB per octave], respectively, cut-off frequency point at -3 dB), connected with an oscilloscope (Gould, Advance Instruments, Model OS250) for on-line monitoring of the signals, and sent to a microcomputer (Olivetti PCS 286) for AD-conversion (Labmaster ADC) and storage. In the imagery condition, the sensitivity of the AD-converter was  $100 \mu\text{V}/\text{Div}$ . Amplifier gain for the active arm was  $1.90 \times 10^3$ , and for the passive arm  $1.95 \times 10^3$ . The difference between

both amplifiers was not considered to be of great importance, because the EMG-signals were rectified to microvolts and further analyses were based on the changes in the rectified EMG. Sample frequency of the AD-converter was 400 Hz.

### *Data Collection Procedures*

Participants were tested individually. Following a brief explanation of the aim and procedure of the experiment, participants completed the MIQ. The experimenter then demonstrated the dumbbell task and attached the EMG electrodes. Participants performed (while standing) six active lifting movements with their preferred hand, utilizing either a 4.5-kg or a 9-kg dumbbell. Each movement took 5 s to perform, with the beginning of each movement indicated by a tone delivered by headphones. After 2.5 s, a new tone informed the participants that they should be halfway through the movement. In addition to the real movements, the participants were instructed to imagine six lifting movements in the same tempo as the real movements. The beginning of the movement was again indicated by a tone that was repeated after 2.5 s. For half of the participants the instructions emphasized stimulus propositions; for the other half, response propositions were emphasized.

Participants then performed six active lifting movements again, using the same weight, followed by six imaginal lifting movements, this time with the other type of propositions emphasized in the instructions. This procedure was repeated for the second weight (9 or 4.5 kg), which led to four imagery conditions: response propositions, 4.5 kg (A); stimulus propositions, 4.5 kg (B); response propositions, 9 kg (C); and stimulus propositions, 9 kg (D). These four conditions were arranged into four different orders (A-B-C-D, B-A-D-C, C-D-A-B, and D-C-B-A) and each participant was randomly assigned to one of these orders. The distribution of inexperienced participants and experienced body builders (inexperienced participants given first) was 6 and 3, 8 and 3, 7 and 2, and 8 and 2, respectively, for the four orders. Immediately following each imagery task, participants completed the Imagery Rating Scale to indicate how easy/difficult it was to imagine the dumbbell lifting. Preceding the first imagery trial of each condition participants were instructed to stand comfortable and relaxed, while waiting for the first tone. This took about one minute.

The instructions for imagining the movement in which response propositions were emphasized were as follows (i.e., the instructions emphasizing stimulus propositions are placed between parentheses):

I would like you to imagine (visualize) the environment we are in here. Maybe it is easier to do so by closing your eyes. Attempt to feel (see) yourself standing close to the apparatus and imagine that you are (see yourself) holding the dumbbell in your right/left hand. After you have heard the first tone, feel (see) yourself lifting the dumbbell and, at the next tone, feel (see) yourself bringing the dumbbell back to the starting position. You will hear the next tone, and again, feel (see) yourself lifting the dumbbell, etc. You will execute six movements that way, just as you did before when you made real movements. Attempt to feel (see) yourself executing the movements all the time, but do not make real movements. Just feel (watch) yourself lifting the dumbbell.

### *Collection of EMG data*

For each participant, EMG activity in each of the four experimental conditions (stimulus or response propositions and 4.5 or 9 kg) was measured. EMG activity was operationalized as the difference between the mean EMG (averaged over the six trials) and the baseline score, averaged over the 15 s prior to the first imagery trial of the condition in question.

## **Results**

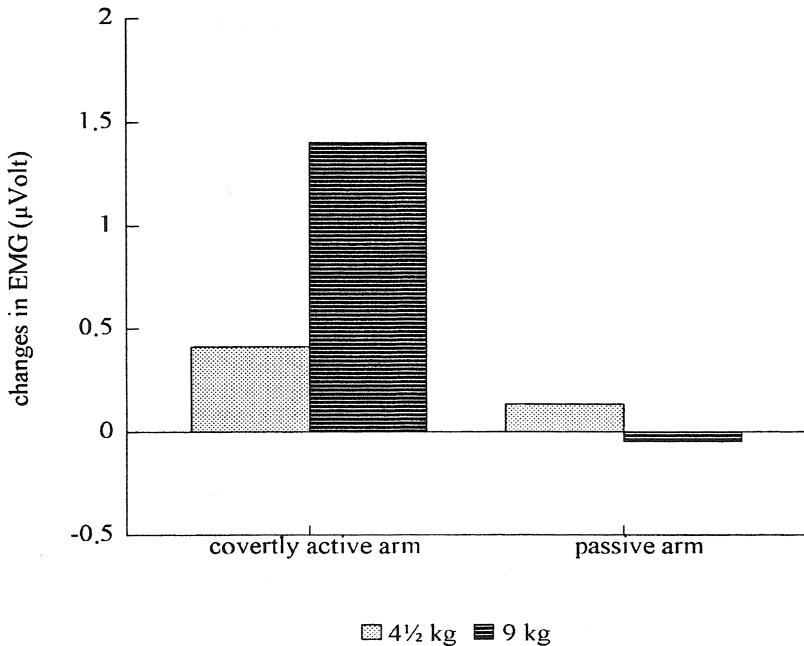
### *EMG Activity*

The first study hypothesis specified that study participants' muscular activity (as measured via EMG recordings) would be greater under response proposition instructions than under stimulus propositions. The second hypothesis specified that study participants' muscular activity would be greater in the active arm than in the passive arm and that imagining the lifting of a heavy object would result in more muscular activity than would imagining the lifting of a lighter object. To test these hypotheses, a  $2 \times 2 \times 2$  (Imagery Instructions  $\times$  Arm  $\times$  Weight) ANOVA, with repeated measures on all three factors, was run. The independent variables included imagery instructions (stimulus or response propositions), arm (passive or active), and dumbbell weight (4.5 or 9 kg). The dependent variables were the difference scores representing participants' muscular activity during imagery, relative to baseline EMG activity.

The results of this repeated measures ANOVA revealed a significant main effect for imagery instructions,  $F(1, 38) = 5.58, p < .05$ . Imagery emphasizing response propositions ( $M = 0.969 \mu\text{V}$ ) produced greater biceps activity than the imagery condition in which stimulus propositions were emphasized ( $M = -0.029 \mu\text{V}$ ). The main effect of arm was also significant,  $F(1, 38) = 3.99, p < .05$ . EMG activity of the active arm ( $M = 0.908 \mu\text{V}$ ) was significantly greater than that of the passive arm ( $M = 0.042 \mu\text{V}$ ). The main effect of weight was not significant ( $F < 1$ ); the interaction between weight and arm, however, proved to be significant,  $F(1, 38) = 4.13, p < .05$ . A Student-Newman-Keuls post hoc test ( $p < .05$ ) showed that EMG activity in the active arm differed significantly between 9 kg and 4.5 kg, whereas EMG activity in the passive arm did not (see Figure 1). Of interest is the three-way interaction among imagery instructions, arm, and weight. Although this interaction just failed to reach significance,  $F(1, 38) = 3.78, p < .06$ , more EMG activity was observed in the active arm when participants imagined lifting the 9 kg dumbbell and when response propositions were emphasized than in any of the other conditions.

### *Imagery Ability and EMG Activity*

The third study hypothesis was that study participants who produce muscular patterns during imagery that are more similar to the actual movement, would have higher imagery ability scores than participants who produce patterns that are less similar to the actual movement. To test this hypothesis, first an EMG activity index was computed for each participant. This index was defined as the difference in EMG activity between lifting of a 9 kg and 4.5 kg dumbbell. The EMG activity index was computed for imaginal lifting, and only for the covertly active arm when



**Figure 1 — Mean change in muscular activity of the dominant, “active” arm and the passive arm during the imagined lifting of the 4.5 and 9 kg weights.**

response propositions were emphasized in the instructions. Since active lifting of a 9 kg dumbbell requires more muscular activity than lifting of a 4.5 kg dumbbell, a positive EMG activity index for imaginal lifting can be considered indicative for better imagery compared to a negative index. Although 25 participants showed more EMG activity during imaginary lifting of 9 kg than of 4.5 kg ( $M_{\text{EMG-index}} = 3.53 \pm 8.49$ ), the opposite was true for the remaining 14 participants ( $M_{\text{EMG-index}} = -0.89 \pm 1.24$ ). Then the scores on the kinesthetic subscale of the MIQ and the Imagery Rating Scale (kinesthetic),<sup>2</sup> filled in after imaginary lifting the dumbbells, were compared by an ANOVA for both groups (a positive vs. a negative EMG activity index). These analyses did not show any significant results,  $F(1, 36) = 1.01$  and  $p = .32$  for the MIQ-kinesthetic subscale;  $F(1, 37) = .08$  and  $p = .77$  for the Imagery Rating Scale (kinesthetic). Evidently, participants who showed a positive EMG activity index during imaginal lifting did not have higher scores for imagery ability than participants who showed a negative EMG activity index.<sup>3</sup>

To investigate the relationships between the self-report measures of imagery ability, the intercorrelations between the scores on the kinesthetic and visual subscales of the MIQ and the Imagery Rating Scale were computed. Mean imagery ability score for the visual items of the MIQ was 2.06 ( $SD = 0.97$ ) and for the kinesthetic items 2.38 ( $SD = 0.87$ ), indicating that the participants felt that the movements were relatively easy to imagine. For the Imagery Rating Scale, the mean score for imagery ability (visual) was 2.32 ( $SD = 1.00$ ) when stimulus propositions were emphasized was and 2.69 ( $SD = 1.36$ ) when response propositions



**Table 1** Pearson Product-Moment Correlations Between the Dutch Movement Imagery Questionnaire (MIQ) and the Imagery Rating Scale

	Dutch MIQ	Imagery Rating Scale	
	Visual	Kinesthetic	Visual
Dutch MIQ			
Kinesthetic	.41*	.55**	.33*
Visual		.44*	.57*
Imagery Rating Scale			
Kinesthetic			.37*

Note.  $N = 39$ .

\* $p < .05$ . \*\* $p < .01$ .

were emphasized (kinesthetic), indicating that the participants felt that the lifting movement was also relatively easy to imagine. The correlations between the scores were all significant (see Table 1): participants assessed their imagery ability similar, irrespectively of the specific scale they filled in.

## Discussion

The main hypotheses of this study held (a) that imagery in which response propositions are dominant will produce more EMG activity than imagery emphasizing stimulus propositions, and (b) that the content of an image—in our case the imagined lifting of different weights with the preferred arm—will be reflected in the magnitude and the location of the EMG response. Overall, the results seem to corroborate both hypotheses. In agreement with Lang et al. (1980), our results revealed that during imagery in which response propositions were emphasized, EMG activity of the participants was significantly greater than during imagery in which stimulus propositions were emphasized. Furthermore, EMG activity during imaginary lifting was significantly greater in the active arm compared with the passive arm, and the imaginary lifting of 9 kg resulted in more EMG activity in the active arm than the imaginary lifting of 4.5 kg dumbbells. In addition, there was a nearly significant trend to more EMG activity in the active arm, during imaginary lifting of the 9 kg weight when response propositions were emphasized than in any of the other conditions. These results seem to be in line with Lang's bio-informational model (Lang, 1977, 1979), which holds that the physiological response of an image that contains response descriptions will be specific to the propositional structure of the imagined scene.

Under the assumption that there is a similarity between, on the one hand, stimulus propositions and imagery from an external perspective and, on the other hand, response propositions and an internal imagery perspective, the finding in the present study indicating significantly more EMG activity during imagery in which response propositions are emphasized agrees with the findings of Suinn (1980),

Hale (1982), Harris and Robinson (1986), and Jowdy and Harris (1990). Suinn (1980) claimed that the EMG output of a skier imagining a downhill run mirrored the particular course he was imaging. Participants in Hale's (1982) experiment produced more biceps EMG activity during internal imagery of a dumbbell curl than during external imagery. Harris and Robinson's (1986) study indicated that internal imagery of arm lifts of karate students resulted in significantly more excitation of the deltoid muscle than external imagery of this movement, a difference that was found only for the covertly active arm. Jowdy and Harris (1990) found a significant increase in muscular activity during mental imagery of juggling. Their imagery instruction involved both stimulus and response propositions. There appears to be a general trend to evoke a raise of EMG activity during imagery, especially when people use imagery from an internal perspective.

In Lang's theory (1977) the propositional structure of the imagined scene refers to specific response systems; for example, imagery scripts that include respiratory, heart rate, or muscle tension propositions will elicit more activity in these response systems than will scenes that do not contain these elements. The difference found in the present study between EMG activity of the active (dominant) and the passive arm, as well as the difference between EMG activity in the active arm during imaginary lifting of 4.5 and 9 kg weights, indicates that the content of the image is related to the location and magnitude of the physiological response. These results suggest, contrary to the findings of Shaw (1938), that the physiological response is also specific within one response system and reflects the spatial differentiation (between passive and active arm) and the quantitative characteristics of an image.

With respect to the latter characteristics, however, it should be noticed that the difference in EMG activity between the 9 kg and 4.5 kg weight in the active arm when response propositions were emphasized in the script, failed to reach significance. Furthermore, the difference in muscular activity found during the imagined lifting of a heavy and a much lighter weight does not necessarily mean that the subsequent lifting of three or more dumbbells of different weight will also result in distinct magnitudes of physiological activity. Given Bernstein's (1967) principle of functional nonunivocality, which implies that there does not exist a one-to-one relationship between neural activation and motor actions, it is unlikely that the content of an image is reflected in all detail in concomitant EMG activity. It is an empirical question to find out how detailed the EMG response mirrors the image.

The individual differences that were evident in the EMG measures were not reflected in the subjective reports of imagery ability. The results indicated that participants who produced EMG activity during imagery that was more similar to the muscular activity during active lifting did not have better imagery ability than participants who produced EMG activity during imagery that was less similar to EMG activity during active lifting. These findings are in contrast with the hypothesis that participants who produce more specific muscular activity patterns are better imagers than participants who produce less specific muscular activity patterns. Several other studies, however, also failed to find a relationship between imagery ability and muscular activity. Hale (1982) did not find a relationship between subjective vividness ratings of kinesthetic sensations and EMG activity in his experiments. Muscular activity was also unrelated to scores on the Betts Questionnaire Upon Mental Imagery (QMI) Vividness of Imagery Scale (Sheehan, 1967)

in Hale's experiment. Finally, Jowdy and Harris (1990) could not demonstrate any significant differences in muscular activity between high and low imagery ability groups (based on MIQ scores) during juggling.

Hecker and Kaczor (1988) concluded that self-rated imagery ability (assessed by the Betts QMI) was not an accurate predictor of physiological responses. Because correlations between subjective and objective measures of imagery ability appear to be low (Finke, 1989; Richardson, 1967), one might question the validity of self-report measures of imagery ability. On the other hand, the consistency of the self-report measures, reflected in the high intercorrelations between them, indicate at least that self-reported imagery ability is a reliable measure.

In conclusion, it appears that imagery instructions that contain response propositions produce a greater physiological response than does imagery that primarily involves stimulus propositions. If an image is directed to a certain limb or muscle, the latter will show an increase in EMG activity (i.e., movement imagery results in spatially differentiated concomitant muscular activity). Furthermore, the EMG activity during imagery reflects the force characteristics of the image. The results seem to sustain the assumption that Lang's theory, specifically the concept of the image as a response prototype, is a suitable framework for studying movement imagery and explaining beneficial effects of imagery in sport.

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## Notes

<sup>1</sup> During movements of one limb, muscles of the contralateral limb may also be activated. This phenomenon is called contralateral innervation or excitation (see Schmidt & Thews, 1983, Williams, Warwick, Dyson, & Bannister, 1989). One should consider the magnitude of the observed increase in activity. A good example is the contralateral extensor or crossed reflex (see Kandel, Schwartz, & Jessell, 1991; Schmidt & Thews, 1983), which is very pronounced in some CVA-patients (Oosterhuis, 1992).

<sup>2</sup> Because the main effect found for Imagery instructions showed that only response propositions resulted in an increase in muscular activity, the analysis between muscular activity and imagery ability was only conducted for the kinesthetic subscale of the MIQ and the Imagery Rating Scale, filled in after response propositions were emphasized (kinesthetic).

<sup>3</sup> The relationship between EMG activity index for imaginal lifting and self-reported imagery ability scores was also examined by a correlational analysis, but this analysis did not lead to a different conclusion. The Spearman nonparametric correlation coefficient between EMG activity index and MIQ kinesthetic score was  $r_s = -.05$  ( $p > .05$ ,  $N = 39$ ); between EMG activity index and Imagery Rating Scale, this coefficient was  $r_s = .21$  ( $p > .05$ ,  $N = 39$ ).

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